Two-level quantum dot in Aharonov-Bohm ring: towards understanding "phase lapse"

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The “phase lapse” is a phenomenon which is characterized by a sudden decay of the phase shift [1, 2] measured for the quantum dot (QD) in Aharonov-Bohm geometry, when the gate voltage shifts the dot energy levels with respect to chemical potential of the leads. There were several theoretical attempts (see for example [3, 4]) to describe this unusual feature, but non of them seems to be satisfactory.

In the present work the evolution of the phase shift is investigated for a model of two-level quantum dot placed in one of the arms of Aharonov-Bohm ring. The levels have different hybridization strength to the leads; one is well coupled to the leads and conducting, and the second is sharp in energy scale and non-active in transport. The orbital quantum number is not conserved while hopping process of electrons between the dot and the leads. As a consequence both the levels are coupled to each other via the leads. It causes a considerable deviation from the usual electron's wave phase shift behavior which changes from zero to π when QD level crosses effective Fermi energy. In particular, a lapse of the phase appears. It corresponds well with recent experimental observations of the phase evolution for the QD in Aharonov-Bohm geometry in the limit of small electron number in the dot [2]. The influence of the direct transmission channel and external magnetic field perpendicular to the plane of the device is also discussed.

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